The Diagnosis of Root Caries

D.W. Banting
Professor, Division of Community Dentistry
School of Dentistry
Faculty of Medicine & Dentistry
The University of Western Ontario
London, Ontario, Canada N6A 5C1

A presentation to the NIH Consensus Development Conference on Diagnosis and Management of Dental Caries Throughout Life

Washington, D.C.

March 26-28, 2001

Introduction

It is not surprising that the Research Triangle Institute (RTI) Evidence Report on the Diagnosis and Management of Dental Caries (2000) found no assessments on the diagnosis of root caries. There simply are no reports in the literature evaluating diagnostic methods for root caries that satisfy all four of the principal inclusion criteria of that review: histological validation, commercial availability, professional application and reports based on comparative clinical studies.

Nevertheless, the literature on the diagnosis of root caries can provide instructive insight regarding diagnosis for the development of consensus statements. A search of the Premedline and Medline databases using the Ovid search engine with the keywords “root caries”, “root surface caries”, “cemental caries”, “(cementum or cemental) and caries”, and “(diagnos$ and screen$)” with Boolean operators revealed 46 citations on the topic.

The Natural History of Dental Caries

The dental caries process begins with the loss of calcium ions from the surface apatite crystals that form the bulk of the three calcified dental tissues. Under normal circumstances, this loss of calcium (demineralization) is compensated by the uptake of calcium (remineralization) from the tooth’s microenvironment. This dynamic process of demineralization and remineralization takes place more or less continually and equally in a favourable oral environment. In an unfavourable environment, the remineralization rate does not sufficiently neutralize the rate of demineralization and caries occurs.

The natural history of dental caries can be viewed as a continuum, a series of stages, from microscopic demineralization of apatite to an active, cavitated, progressively enlarging lesion (Dodds & Wefel, 1995) (Figure 1). The latter part of this continuum has been divided arbitrarily into stages and assigned labels such as early, white spot, incipient and advanced that assist us when making decisions regarding clinical management. Diagnosis of caries involves primarily visual-tactile methods but radiographs are also extensively used.

There is a general consensus among clinicians that for coronal caries, restorative treatment is indicated if the lesion is cavitated and extends into the dentine (Community Dental Health Research Unit, 1995). There is no such consensus regarding root caries. Root caries can involve the cementum first but, in most situations, it begins in the dentine (Figure 2). There is no white-spot lesion associated with root caries and the clinical stages of the disorder have been arbitrarily divided into stages based on the texture and the depth of the surface defect (Billings et al, 1985; Billings 1986).

Clinical studies have convincingly demonstrated that the caries process, whether it involves the crown (enamel) or the root (cementum, dentine) of the tooth can be reversed or, at least, arrested, even if the tooth surface is cavitated. Reversing the caries process (remineralization) is probably dependent more on the microenvironment surrounding the tooth or adjacent to a particular tooth surface than on the size or extent of the existing lesion. However, while the caries process can be interrupted at virtually any point, any loss of structure cannot be replaced. For coronal caries involving the enamel, loss of structure implies loss of mineral. For coronal caries involving the dentine and for root caries, there is both loss of mineral and loss of protein (proteolysis). Remineralization involving the dentine has been shown to take place on the remaining mineral content rather than on the protein infrastructure (Wefel et al, 1985).

It is not known exactly how long it takes for a coronal caries lesion to develop because our diagnostic tools are not yet sensitive enough to pick up sub-clinical lesions or the very early clinical stages of the disease. However, once a carious lesion is diagnosed clinically, it is possible to trace its development or progression. In general, caries progression within the enamel of permanent teeth is a slow process, requiring an average of three or four years to reach dentine (Community Dental Health Services Research Unit, 1993). Within dentine, caries progression is not as well documented as most caries that reaches the dentine is treated with a restoration before it progresses deeply into the dentine. The progression of root caries, being essentially dentinal caries, is also largely undocumented.

It will be possible, with the use of emerging technology, to shift the diagnostic decision regarding the presence of decalcification (dental caries) further to the left- to the area of very early lesion development or, in fact, to a point beyond our ability to visualize the disease in the mouth. This ability to diagnose dental caries earlier in its natural history at a point even before we can visualize it clinically has several attractions. It would allow clinicians to manage the caries process at an earlier stage and initiate preventive rather than treatment measures. And, it will obviate the need to surgically correct the disorder thereby introducing cost savings, assuming that medical treatment is less costly than surgical treatment.

Since this Consensus Conference has been charged with the task of determining the “best methods for detecting early-stage and late-stage dental caries”, this presentation will discuss the clinical diagnosis of root caries by examining the validity and reliability of traditional visual-tactile methods and the use of existing diagnostic tests to supplement visual-tactile assessments.

Epidemiology of Root Caries

There is little disagreement in the literature regarding the distribution of root caries lesions. Root caries, by definition, occurs on the root of the tooth. Some investigators have made a distinction between root caries that originates wholly on the root surface and caries that spreads from the coronal surface onto the root surface. Lynch (1994) refers to caries that begins on the root surface as “primary root caries”. The term “primary” as it is used with root caries refers to new dental caries occurring in the absence of a restoration. Secondary (recurrent) root caries refers to caries occurring adjacent to an existing restoration. There is already general agreement on this terminology.

Clinical researchers agree that root caries can occur anywhere on the root surface. But, there are conflicting views about root lesions in the area of the cemento-enamel junction (CEJ) as to whether the initial caries occurred on the crown or the root of the tooth. With location, the issue is whether or not to classify caries in the area of the CEJ as root caries extending onto the crown, as coronal caries extending onto the root or both. This, however, is a measurement issue more than a diagnostic issue.

Root caries occurs supragingivally, most often at or close to (i.e. within 2mm) the cemento-enamel junction. This phenomenon has been attributed to the location of the gingival margin at the time conditions were favorable for caries to occur (Banting, 1976; Banting et al, 1985; Lynch and Beighton, 1994). The location of root caries has been positively associated with age and gingival recession and this is consistent with the concept that root caries occurs in a location adjacent to the crest of the gingiva where dental plaque accumulates. Root caries occurs predominently on the proximal (mesial and distal) surfaces, followed by the facial surface (Banting et al, 1985; Schaeken et al, 1991, Fure, 1997; Banting et al, 2001).

Early root caries tends to be diffuse (spread out) and track along the cemento-enamel junction or the root surface. More advanced root lesions begin to progress toward the pulp much like dentinal caries in the tooth crown.

Several reviews of root caries have been published in the past decade (Beck, 1990; Hellyer and Lynch, 1991; Titus, 1992; Billings and Banting, 1993; Ravald, 1994) and readers are directed to them for further information.

Similarities and Differences between Coronal and Root Caries that Influence Diagnosis and Management

There are many similarities and a few differences between coronal and root caries that necessitate different approaches to and criteria for clinical diagnosis (Table 1).

Coronal and root caries share common risk factors (mutans Streptococci, Lactobacilli), common predisposing factors and appear to share a similar process of dentine destruction and remineralization (Wefel et al, 1985; Frank, 1990; Schupbach et al, 1989,1990; Zambon and Kasprzak, 1995). There are, however, subtle differences related to the pH at which demineralization begins, the role of proteolytic enzymes in the destruction of the initial target tissue and the rate of lesion progression.
Some investigators, nevertheless, consider coronal and root caries to be similar disorders (Billings and Banting, 1993).

The diagnostic criteria for coronal and root caries differ primarily because of the composition of the tissues forming the outer layer of the crown and root respectively (Scott and Symons, 1974; Provenza, 1988). Coronal caries almost always begins in highly mineralized enamel. Root caries, however may involve the less mineralized cementum first or, more likely, the dentine which is also contains much less mineral than enamel. The cemento-enamel junction can have cementum overlapping enamel (60-65%), cementum abutting enamel (25-30%) or a space between the cementum and the enamel where dentine is exposed (10%) and even all three situations on the same tooth (Scott and Symons, 1974; Provenza, 1988). Because of the thinness of the cementum in this region of the root, and the extent to which scaling and root planing procedures are routinely applied in developed countries, there is a high probability that the cementum has been removed in the area of the cemento-enamel junction and the coronal third of the root. Therefore, root caries is, for all intents and purposes, dentinal caries.

Clinical Signs of Root Caries

Clinical diagnosis is the process of recognizing diseases by their characteristic signs and symptoms. It is an imperfect process because there is considerable variation both in the signs and symptoms of disease in individual subjects and in the interpretation of those signs and symptoms by clinicians. Nevertheless, clinical observations are extensively relied upon for diagnosis in the absence of more definitive methods.

The clinical investigators who first studied root caries provided clinical descriptions of the signs and symptoms of root caries lesions (Hazen et al., 1973; Sumney et al., 1973; Hix and O'Leary, 1976; Banting et al., 1980; Katz et al., 1982; Vehkalahti et al., 1983; Beck et al., 1985; NIDR, 1987). The most commonly used clinical signs to describe root caries utilized visual (color, contour, surface cavitation) and tactile (surface texture) specifications (Banting, 1993). There are no reported clinical symptoms of root caries although pain may be present in advanced lesions. (Table 2).

There are intriguing contrasts in the description of the contour, cavitation and color aspects of a root caries lesion. Sumney et al. (1973) found root caries lesions to be "shallow and ill-defined". Hix and O'Leary (1976) describe root caries lesions as "well-established". Banting et al. (1980), in direct contrast to Sumney et al. (1973), consider root caries lesions to be "discrete” and “well-defined" lesions. Several investigators describe the root caries lesion as "discolored" or "darker" while others indicate that there is a specific color change to "yellow/orange", "tan" or "light brown" associated with the root caries process. Although no correlation has been demonstrated between the color of root lesions and caries activity (Hellyer et al, 1990; Shaeken et al, 1991, Lynch and Beighton, 1994), it is unanimously agreed that discoloration of the root surface is indicative of the presence of caries.

Although root caries is referred to as a "lesion", it is not at all clear whether a cavity (or loss of surface continuity) must necessarily be present in the early stages of the disease. Whether a probe needs to be used to confirm loss of surface continuity has generated considerable debate for coronal caries diagnosis and the arguments would likely apply equally well for root caries diagnosis. Nevertheless, clinical investigators are in agreement about active root caries being "soft" when gently probed with an explorer.

The presence of cavitation is often difficult to determine visually and thus probes are used to detect surface defects. On enamel, it is possible to run the probe across the surface and detect a roughness that is indicative of cavitation. On cementum or dentine, however, this is not as easy to do. The lower degree of mineralization of cementum and dentine does not permit the probe tip to glide freely over the surface when the surface is intact.

Tactile diagnosis of caries has used probe “tug back” as a sign of the presence of caries. This has served the clinician well in coronal caries where the caries extends into the dentine. Dentine caries is soft, relative to the enamel and the presence of this softness, as evidenced by a “tug back” on the probe has been used to indicate dentinal caries. However, non-carious dentine and cementum are “soft” calcified tissues and can produce some “tug back’ on the probe in the absence of caries. Assuming that the probing pressure used is the same, the presence of “tug back” on the root surface is, therefore, more likely to result in a false positive diagnosis of dental caries. Nevertheless, texture, is used extensively used by clinicians to aid in the determination of root caries.

The traditional methods of visual-tactile diagnosis for root caries can produce a correct diagnosis but usually not until the lesion is at an advanced stage. Because of the fundamental differences in coronal and root caries, coronal caries is more likely to be confidently diagnosed at an earlier stage than root caries using visual-tactile methods. Setting aside the argument that probing can hasten the development of caries, the disadvantage of diagnosing root caries using visual-tactile methods is that a larger or more advanced surface defect needs to be present before a positive diagnosis can be made.

Clinical investigators have advocated expanded categories for visual-tactile root caries diagnosis (Fejerskov et al, 1991) (Table 3). These provide the clinician with additional information regarding the root lesion that can be helpful for describing the physical characteristics of the lesion. Although these expanded criteria are useful for research purposes, their usefulness to the clinician is limited for determining whether or not root caries may be present. These expanded criteria, however, have been used to classify root lesions according to their activity (Table 4). Unfortunately, color has not been found to be well correlated with root caries activity and probing pressure can be highly variable.

Combinations of signs have been related to potential treatment protocols for root caries (Beighton et al, 1993; Lynch and Beighton, 1994) (Table 5). This can provide a guideline for clinicians regarding the most appropriate treatment to provide for a given root lesion.

Although more categories of signs and symptoms can provide more information and, therefore, for more precision in the diagnostic process, they also generate more variability in the diagnosis.

Reliability of Visual-Tactile Diagnosis of Root Caries

Despite the subjectivity that is inherent in interpreting the clinical signs used for root caries diagnosis, good to excellent inter-examiner reliability has been reported in clinical studies. Table 6 presents several measures of examiner reliability reported in studies conducted in the past decade or so involving the clinical diagnosis of root caries.

At face value, these examiner reliability results are impressive for human clinical studies. However, when the examiner reliability measurements are examined more closely, it is apparent that the presence of filled surfaces dramatically enhances the agreement. Filled surfaces represent the largest single component of caries experience indices. When only untreated root caries is diagnosed, examiner reliability is reduced considerably (Rosen et al, 1996, Banting et al, 2001). Intra-examiner reliability has been shown to be slightly, but not dramatically, better than inter-examiner reliability for the diagnosis of root caries (Rosen et al, 1996).

Clinical disagreement in root caries diagnosis can be attributed to several factors. Variation in an examiner's visual acuity (e.g. presbyopia, color blindness) can obviously affect the interpretation of the presence or absence of cavitation and/or a color change on the root surface. Even more critical, however, is that there is frequently disagreement between examiners concerning the relative softness or hardness of the area examined due to differences in interpreting tactile sensitivity.

Accuracy of Clinical Diagnosis of Root Caries

Given the lack of uniformity regarding the clinical description of root caries it is natural to question the accuracy of clinical diagnosis. Accuracy reflects the closeness of a clinical observation to the true condition.

There are no in vivo studies reported in the literature that compare clinical diagnosis with a histological assessment of the lesion. Although this is disappointing, it is not surprising because of the difficulty of conducting studies where teeth are removed and histologically examined following clinical examination. Interestingly, there is a similar paucity of in vitro studies of root caries that compare clinical diagnostic signs with the histology of the area. Most of the in vitro studies use a clinical assessment as the standard. A recent study of secondary caries at the crown margins, most (52%) of which were on the root surface, showed a strong correlation (rho = 0.87) between the secondary caries index used and the histological evaluation. (Zoellner et al, 2000).

Diagnostic Tests for Root Caries

The validity of a diagnostic test is usually established by comparing its results to clinical opinion. Once validity is established, the test is then used to confirm the diagnosis determined on the basis of the clinical signs and symptoms. The paradox of this reasoning is that the performance of the diagnostic test is dependent upon the accuracy of the clinical diagnosis which, in the absence of histological assessment, cannot be directly determined. If the diagnostic test is compared with the clinical standard, the diagnostic test may appear worse even when it is actually better. If the diagnostic test is more sensitive (i.e. it is positive when the disease is present) it will identify more occurrences of disease and these will be considered as false positive in relation to the clinical diagnosis. Therefore, if an inaccurate clinical standard is used, a new diagnostic test can only perform as well as, but never better than, that clinical standard. Similarly, if the diagnostic test is more often negative in the absence of disease it gives rise to more false negative findings relative to the clinical diagnosis. Therefore, the diagnostic test will appear inferior when it actually approximates the truth more closely (Fletcher et al., 1988).

Clinicians look to diagnostic tests in the hope that they will perform better (i.e. be more reliable) than clinical diagnosis and, therefore, can be used to replace clinical diagnosis. The point of this discussion, however, is to examine how diagnostic tests can supplement a clinical diagnosis of root caries. In other words, can a diagnostic test increase or decrease the clinician's "best guess" as to whether root caries is or is not present?

Before this is done, however, it is important to emphasize that clinical disagreement is not unique to the interpretation of clinical signs and symptoms. It can be problematical when interpreting the results of a diagnostic test as well. Depending on the test, clinicians can disagree as to whether the test is positive or negative.

Which Diagnostic Test is Best for Root Caries?

Selecting the most appropriate diagnostic test is a complex matter that must take into account test characteristics, prevalence of the disorder and the purpose of applying the test. For screening purposes, a highly sensitive test is generally preferred so that the number of false negative test results, when the disorder is actually present, is minimized. To assist with diagnosis, a highly specific test is preferred so that there will be few false positive test readings in the absence of disease. To confirm a diagnosis for low risk diseases such as root caries, test specificity is crucial while test sensitivity is of lesser importance.
Test sensitivity and specificity, however are uncalibrated measures of test performance. Therefore, it is difficult, and indeed inappropriate, to compare test properties without first calibrating them. Kraemer (1992) provides methods for calibration of test characteristics to measure test quality and counsels that the best test is not necessarily the most sensitive or the most specific test but one where the combination of sensitivity and specificity result in optimal agreement with the clinical diagnosis (test efficiency).

Table 7 presents the characteristics of diagnostic tests that have been used for root caries. Se and Sp represent the well-known test characteristics of sensitivity and specificity respectfully. Kse and Ksp are adjusted or calibrated to account for the mean probability of a positive test for subjects in the population studied and the prevalence of the diagnosis in the population. It is important to notice that when the test characteristics of sensitivity and specificity are calibrated they are generally diminished. This arises because the calibrated values (Kse and Ksp) represent their ability to detect the presence or absence of the disorder beyond chance or the mean probability of a positive test result in that population. In this respect, they are analagous to Kappa statistics (Fleiss, 1981). Comparing the calibrated sensitivities and specificities allow for the determination of the optimally sensitive and optimally specific test from among a group of tests. When comparing the overall performance of diagnostic tests, the most useful clinical measure is test efficiency. Like sensitivity and specificity, test efficiency should be calibrated (Keff) producing an index that is a weighted Kappa statistic expressing the relationship between test result and diagnosis. This value reflects overall test performance and can be used to contrast different tests. The test with the highest Keff is the most clinically optimal test.

From the limited data available on diagnostic tests for root caries, tests determining the presence or absence of mutans streptococci and Lactobacilli are the most clinically helpful producing calibrated efficiency scores exceeding 40%. Although the evidence is strong, it is scanty. For proximal surfaces, radiography produces good results but the supporting evidence is weak. The fluorogenic enzyme assay used by Collier et al (1993) estimates bacterial counts, particularly mutans streptococci and Lactobacilli, in plaque overlying root caries and, therefore, supports the evidence for mutans streptococci and lactobacilli diagnostic tests.

The Risk-Assessment Approach to the Diagnosis of Root Caries

The basic measure of a person's risk is disease incidence i.e. the number of persons who develop the disorder (one or more new root caries lesions) over a given period of time divided by the number of subjects observed. Disease prevalence (i.e. the number of persons with the disorder in a population at any given point in time) is frequently used as a measure of risk but, when determining the quality of evidence, studies that provide incidence data (i.e. experimental and cohort studies) provide a higher level of evidence than studies that produce prevalence data (descriptive studies).

Prospective randomized and non-randomized clinical trials have revealed a wide range of incidence estimates depending on the target population observed and length of the study (Table 8). Older, medically compromised or institutionalized subjects and subjects with advanced periodontal disease are at greater risk. The risk of root caries in the general, community-dwelling population is obviously lower. Leake (2001) estimates that 8.2% of community-dwelling subjects in North America would be expected to acquire one or more new root caries in any year.

A clinical diagnosis is an estimate of the probability that a patient has a specific condition after taking into account the possible risk factors and indicators, clinical findings and how commonly the disease occurs in the population. The information gained during the clinical examination of the patient together with the clinician's knowledge of the disease and his or her own clinical experience is, consciously or otherwise, collated, analyzed and assimilated into a "best guess" of the likelihood of a condition being present. This is the "art" of clinical diagnosis.

Risk assessment involves the determination of a patient's risk and selection of an appropriate diagnostic test if the clinician is unsure of the diagnosis. Matthews at al (1995) describe a useful process to assist the clinician in determining whether or not a diagnostic test is indicated in order to diagnose a disorder (Figure 3). This approach is applicable to all conditions, including root caries, and involves the following steps on the part of the clinician:

1) determine the patient's risk of experiencing root caries based on his/her knowledge, experience and the available evidence from the clinical examination.

Evidence from incidence studies indicates that a reasonable estimate of risk of root caries for adults living in the community is approximately 10%. This becomes that patient's pre-test probability of having the disorder. This "raw" risk estimate must then be adjusted upwards or downwards depending on the presence of clinical signs and the presence of known risk indicators such as previous root caries experience, advancing age, reduced salivary flow rates, poor oral hygiene, a cariogenic diet, inadequate fluoride exposure, etc.

2) establish "test" and "treatment" thresholds for the condition.

Test and treatment thresholds can be determined using a scientifically based calculation (which is comparatively complex) or they can be determined arbitrarily by establishing personal "comfort levels". For example, if the pretest probability of root caries is estimated to be 0.25 or below, there may be no need for a diagnostic test because the additional information provided (even if it is a perfect test) would still leave the clinician uncertain as to the presence of the disease. Similarly, if the likelihood of root caries is 0.75 or greater, a diagnostic test would be unnecessary because the clinician is already quite confident of the presence of the disorder. However, if the clinician estimates the pretest probability to be within the 25-75% range, it may be difficult for the clinician to know what to do and additional information from a diagnostic test could be helpful in confirming or refuting a diagnosis. These “comfort levels” can be changed depending on the accuracy of the diagnostic test, its potential for harm to the patient and its cost and ease of application. If the test is quite accurate and safe, the comfort levels can be spaced farther apart. The opposite is true if the test has low accuracy or is potentially harmful. It makes sense to use a diagnostic test when you are not certain of a diagnosis. But, diagnostic tests should be used as a supplement to a clinical diagnosis- not as a substitute.

3) select an appropriate test

Test properties, availability, cost, ease of administration and potential risks must all be taken into consideration when choosing among diagnostic tests. When selecting a test, the benefit to the patient must outweigh the costs, risks and ease of administration and result in an improved outcome such as earlier diagnosis, the reduction of unnecessary treatment or indicating the appropriateness of a less costly treatment procedure. The best test for root caries has already been identified as the test with the highest efficiency score.

4) administer the test

5) determine the patient’s risk following the diagnostic test results and make a decision regarding management.

This requires some calculation but the process is well described in several places (Fletcher et al, 1988; Sackett et al, 1991; Matthews et al, 1995).

This process of determining risk and basing management on an estimate of risk is foreign to most dental clinicians. Clinicians are frequently uncomfortable with a decision not to use a diagnostic test, especially radiographs, even when the estimate of risk is quite low, because they find it difficult to live with uncertainty. Living with uncertainty in dental diagnosis is difficult to do because dental training has not adequately addressed this aspect of clinical diagnosis. With a disease like root caries, where progression of the disorder is slow and the consequences of the disorder are far from life threatening, or even tooth threatening, a higher level of uncertainty can be justified. If the clinician cannot abide any degree of uncertainty, then rather than watchful waiting, he/she can implement preventive treatment in the form of chemotherapeutic agents (fluoride, antimicrobials). The downside on this strategy is limited to the cost of the preventive treatment.

An example may be helpful. Suppose a new patient presents herself for examination. The patient is an older adult who has been a lifelong resident in a fluoridated area. Your visual examination reveals previous dental caries experience (restored teeth), some suspicious (soft) areas on the roots of some teeth interproximally but no cavitated lesions. Based on the evidence available in the literature regarding the low incidence of root caries in this population group and the slow rate of progression of the disease, your “index of suspicion” should be quite low, somewhere around 0.20. In other words, the probability of these suspicious areas being active root caries is about 20%. With such a low pre-test probability, a diagnostic test would not be indicated because it is below a test threshold level that you have arbitrarily set at 0.25 with a corresponding treatment threshold level of 0.75. However, your examination also revealed that oral hygiene was not good and your medical history related that the patient has been on systemic antihistamines for her allergies for the past year. You also noted in the clinical examination that her saliva flow was diminished although she did not complain of dry mouth. This clinical information would certainly increase your “index of suspicion” of the probability of interproximal root caries. Therefore, you raise the pre-test probability to 0.30 (which is just slightly higher than the test threshold but still a long way from the treatment threshold). With this revised pre-test probability, a diagnostic test may be indicated.
Table 9 presents the post-test probabilities for root caries for this case following the use of a diagnostic test. Using the test data from Scheinin et al (1994), because it represents the highest level of evidence (a three year cohort study), a positive test for the presence of mutans streptococci would increase the probability of root caries from 0.30 to 0.42. The patient’s risk now is midway between the test and treatment thresholds. If the test is negative, the probability of root caries is decreased from 0.30 to 0.10. If a diagnostic test for the presence of Lactobacilli was used, the post-test probabilities are even more revealing.

Consensus on the Diagnosis of Root Caries

A. Terminology

The terminology used for root caries is not standardized and this situation can give rise to confusion, and even misinterpretation, in root caries diagnosis. It is readily apparent that there is, at this moment at least, no unanimity concerning the clinical signs that would confirm a diagnosis of root caries*.*

The first consensus that is required regarding root caries diagnosis pertains to terminology. The terminology associated with root caries needs to be standardized in order to facilitate precision, understanding and uniformity of diagnosis. Once agreement is achieved, it should be possible to devise criteria that are clear, concise and allow little room for independent interpretation by examiners.
A consensus is needed on the definition or meaning of the following specific terms related to root caries lesions:

Active
Inactive (arrested)
Severity
Cavitation (contour)
Texture (hard, leathery, soft)
Primary
Secondary (recurrent)

In attempting to come to a consensus on the clinical signs of root caries diagnosis, it would be short sighted to ignore aspects of the diagnosis that clearly relate to clinical management. Although clinical management of root caries is a topic of a later presentation, it would be desirable to have widespread agreement on the categories of root caries activity and/or severity so that a consensus on the most appropriate management regimens can be developed.

Consideration should also be given to establishing different levels of accuracy of clinical diagnosis. Clinical signs can be employed singly or combined to produce diagnoses of varying certainty. There are presently no guidelines as to whether only one sign or

several signs need to be present before a clinical diagnosis of root caries can be confidently made. Usually, the more signs that need to be observed in order to confirm a diagnosis the greater the accuracy of the diagnosis. But, fewer cases of the disease would be identified and many subjects who would ordinarily be considered to have the disease would not be included. On the other hand, using just one of the signs to define the presence of root caries probably overestimates the true frequency of the disease. Interestingly, only the National Institute of Dental Research diagnostic criteria for root caries (National Institute of Dental Research, 1987) specify that "visual criteria related to location, shape and discoloration of the suspected area do not, in themselves, define root caries. The tactile criteria of softness to an explorer tip must be met for a definitive diagnosis of root caries to be made."

B. Classification scheme

A classification scheme for root caries diagnosis needs to be developed that will allow for the discrimination between sound and carious areas on the tooth root, the activity of the lesion and the determination of different management choices.

Consensus on a classification scheme or decision tree would greatly assist with the management of the disorder if it could distinguish between the following:

sound/carious root surface
non-cavitated/cavitated root lesion
active/inactive root lesion
observation/treatment options

C. Visual-tactile Diagnosis

Visual-tactile methods are widely used to diagnose root caries and represent the best clinical procedure currently available for detecting early and advanced lesions. There is no evidence available with respect to the accuracy of visual-tactile diagnostic methods for diagnosing root caries. However, there is good evidence (II-2) to indicate that inter-examiner reliability is considerably better than chance for the diagnosis of root caries particularly when restored root lesions are included. When only non-restored lesions are considered, reliability is reduced dramatically. Limited evidence (III) exists to show that intra-examiner reliability is better than inter-examiner reliability for the diagnosis of root caries.

D. Risk assessment

Risk assessment methodology can be a useful approach to clinical diagnosis but is not presently widely used in dentistry. There is good evidence (II-2) respecting the incidence of the disorder in both community-dwelling and special population groups and fair to good evidence (II-2, II-3) supporting the use of diagnostic tests to measure predisposing factors or risk indicators. The best indicators at this time for root caries are past caries experience and the presence of microorganisms (mutans streptococci and Lactobacilli) for the disorder.

E. Diagnostic tests

Diagnostic tests can be useful for the clinical diagnosis of root caries. However, they are best used to confirm or supplement a clinical opinion, not as a substitute for clinical decision-making. There is fair to good evidence (II-2, II-3) to support the use of certain microbiological diagnostic tests for root caries diagnosis. Advances in technology will lead the way to better diagnostic tests for root caries but, at this time, however, there is insufficient evidence available supporting the use of radiographs or dyes.

A consensus is needed on the following aspects of diagnostic tests for root caries:

> **1. When should a diagnostic test be used?**
> **2. What diagnostic tests are useful and practical?**
> **3. How should a diagnostic test be used to determine a diagnosis regarding root caries?**

Areas for future research pertaining to the diagnosis of root caries.

In undertaking future research related to the diagnosis of root caries, the following areas should be considered:

1. examination of the accuracy (validity) of the visual-tactile clinical signs used to diagnose root caries by comparing them to a histological standard,

2. undertaking in vivo studies of existing and new diagnostic tests for root caries comparing them with both the clinical diagnosis and a histological standard,

3. identification of the characteristics of diagnostic tests for root caries including an analysis of test quality, particularly test efficiency, so that tests can be directly compared with one another.

Table 1- Similarities and differences between coronal and root caries

	Coronal caries	Root caries
Surface tissue	enamel	cementum or dentine
Risk factor	mutans Streptococci Lactobacilli	mutans Streptococci Lactobacill
Predisposing factors	oral hygiene diet salivary flow fluoride exposure	oral hygiene diet salivary flow fluoride exposure
Composition (by weight)	Enamel-95-97% mineral 3-5% organic & water Dentine-65-70% mineral 30-35% organic & water	Dentine-65-70% mineral 30-35% organic & water Cement-45%-55% mineral 45-55% organic & water
Histopathology	primarily demineralization	demineralization and proteolysis
PH	demineralization occurs at pH 5.5	demineralization can begin at pH 6.7
Enamel	bacterial invasion followed by demineralization	n/a
Cementum	n/a	bacterial invasion followed by demineralization and proteolysis occurring simultaneously
Dentine	bacterial penetration of tubules, demineralization of intertubular dentine, sclerosis of lumens of dentine tubules, destruction of lumens and peritubular dentine,	bacterial penetration of tubules, demineralization of intertubular dentine, sclerosis of lumens of dentine tubules, destruction of lumens and peritubular dentine,

	proteolysis of the organic component	proteolysis of the organic component
Remineralization	occurs on remaining mineral	occurs on remaining mineral (not on collagen matrix devoid of mineral)
Lesion progression	it takes 3 to 4 years for caries to progress through enamel time to progress through dentine is unknown	time to progress through cementum is unknown time to progress through dentine is unknown

Table 2- Clinical signs of root caries

	Signs
Visual	Color Contour Cavitation
Tactile	Texture

Table 3- Categories associated with the clinical signs of root caries

Sign/Decision	Categories
Color	yellow light brown dark brown black
Dimensions	length (mm) width (mm)
Contour or Cavitation	depth (mm)
Gingival margin	distance (mm)
Texture	soft leathery hard
Plaque	visible on lesion

Table 4- Categories of root caries activity

Activity	Clinical signs
Inactive (arrested, remineralized)	well-defined dark brownish or black in color smooth, shiny surface hard on probing with moderate pressure usually not covered with plaque cavitation may be/is present
Active	yellowish, light brown soft or leathery on probing with light pressure covered by visible plaque cavitation may or may not be present

Table 5-Treatment protocols for root caries

Treatment Protocol	Clinical Signs
No treatment	hard lesions
Chemotherapeutic agents	leathery to hard, easily cleaned
Debridement	leathery, able to maintain plaque-free
Debridement and restoration	large, leathery with loss of contour soft, unable to maintain plaque-free

Table 6- Reliability of visual-tactile diagnosis of root caries

Investigator	Kappa statistic (qualitative)	Intra-class correlation coefficient (quantitative)	Per cent agreement
Bauer et al, 1988		0.83-0.96	
Fejerskov et al, 1991	0.88		
Saunders & Handelman, 1991			90
Graves et al, 1992		0.94	
Ravald and Birkhed, 1991	0.71		87
Wallace et al, 1993	0.80		98
Mojon et al, 1995	0.61[1]		
Rosen et al, 1996	0.30-0.51[1]	0.55-0.75[1]	
Lawrence et al, 1996		0.67-0.92	
Locker, 1996	0.60		97.5
Fure, 1997		0.86-0.97	
Powell et al, 1998		0.96-1.00	
Gilbert et al, 2001	0.69		99
Banting et al, 2001		0.91, 0.65[1]	

1. caries diagnosis only- does not include filled surfaces

Table 7- Characteristics of diagnostic tests for root caries

Test	Study Type	Se %	Sp %	Kse %	Ksp %	Keff* %	Other
Mutans Streptococci							
Ravald et al, 1986	cross-sectional	75	100	65	100	79	
Banting, 1988	cohort	46	93	33	63	43	
Ravald and Birkhed, 1991	cross-sectional	36	89	17	54	26	
Scheinin et al, 1994	cohort	88	47	58	25	35	
Lactobacilli							
Ravald et al, 1986	cross-sectional	75	95	63	84	72	
Banting, 1988	cohort	38	74	12	14	13	
Ravald and Birkhed, 1991	cross-sectional	59	84	37	53	45	
Scheinin et al, 1994	cohort	90	57	69	36	48	
Radiology							
Nordenram, 1988	in vitro, cross-sectional	74	87	58	66	62	proximal surfaces only
Salivary secretion rate							
Ravald et al, 1986	cross-sectional	8	100	5	100	10	
Ravald and Birkhed, 1991	cohort	16	95	6	48	11	
Salivary buffer effect							
Ravald et al, 1986	cross-sectional	8	100	5	100	10	
Ravald and Birkhed, 1991	cross-sectional	46	78	18	33	24	
Scheinin et al, 1994	cohort	76	55	38	26	31	
Oral sugar clearance time							
Ravald and	cross-	26	85	7	20	10	

Birkhed, 1991	sectional						
Fluorescent Dye Van der Veen and ten Bosch, 1993; 1996 van der Veen et al, 1996	in vitro						r=0.91-.96 between dye penetration and mineral loss
Fluogenic Enzyme assay Collier et al, 1993	cross-sectional	71	97	35	95	51	r= 0.87 with plate counts of mutans streptococci and Lactobacilli
Diazonium dye Wilkinson et al, 1997	in vitro						descriptive report only

* for root caries, false positives and false negatives have been considered to be equally important

Table 8– Incidence rates for root caries

Study	Type and sample size	Population characteristics	Duration (mos)	Incidence (per cent persons affected)
Banting et al, 1985	cohort (45)	35+ institutionalized	34	35.6
Hand et al, 1988	cohort (338)	65+ community	36	43.7
Leske & Ripa, 1989	cohort (796)	20+ community	36	18.6
Ravald et al, 1993	cohort (27)	46+ periodontally treated	144	88.9
Lawrence et al, 1996	cohort (188 black) (175 white)	65+ community	60	30% (black) 35% (white)
Locker, 1996	cohort (493)	50+ community	36	27.4
Fure et al, 1997	cohort (148)	60+ community	60	72
Powell et al, 1998	randomized clinical trial control group (55)	60+ community	36	77
Gilbert et al, 2001	cohort (723)	45+ community	24	36

Table 9- Pre- and post-test probabilities for root caries using the presence of mutans streptococci and Lactobacilli as diagnostic tests

Pre-test probability	Pre-test probability	Post-test probability with +ve test	Post-test probability with -ve test
Presence of mutans streptococci	0.30	.42	.10
Presence of Lactobacilli	0.30	.90	.08

Figure 1- Natural history of coronal caries

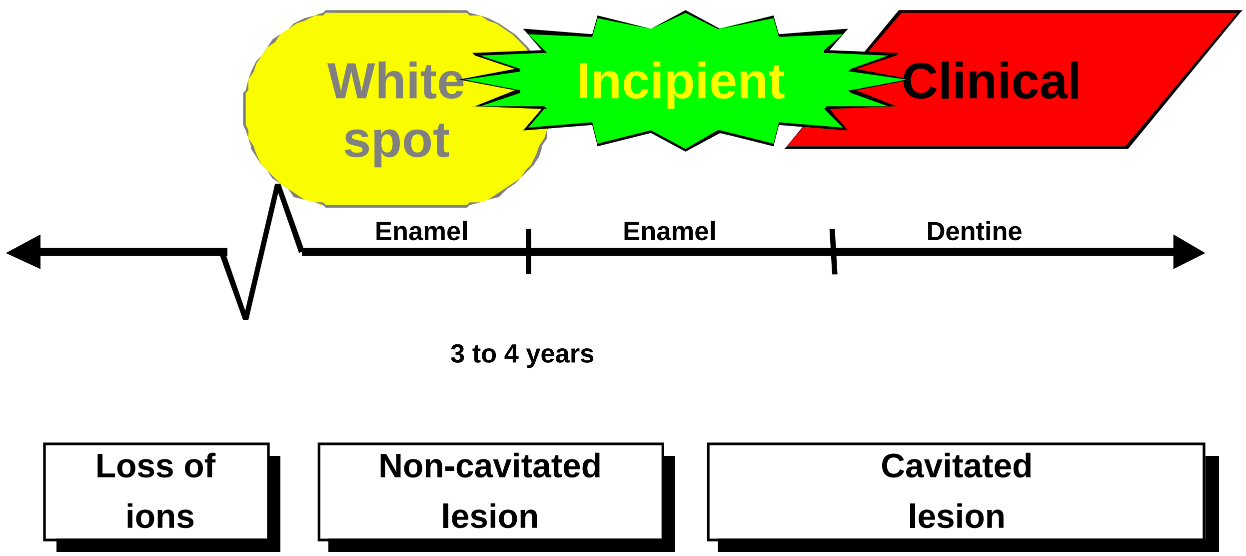
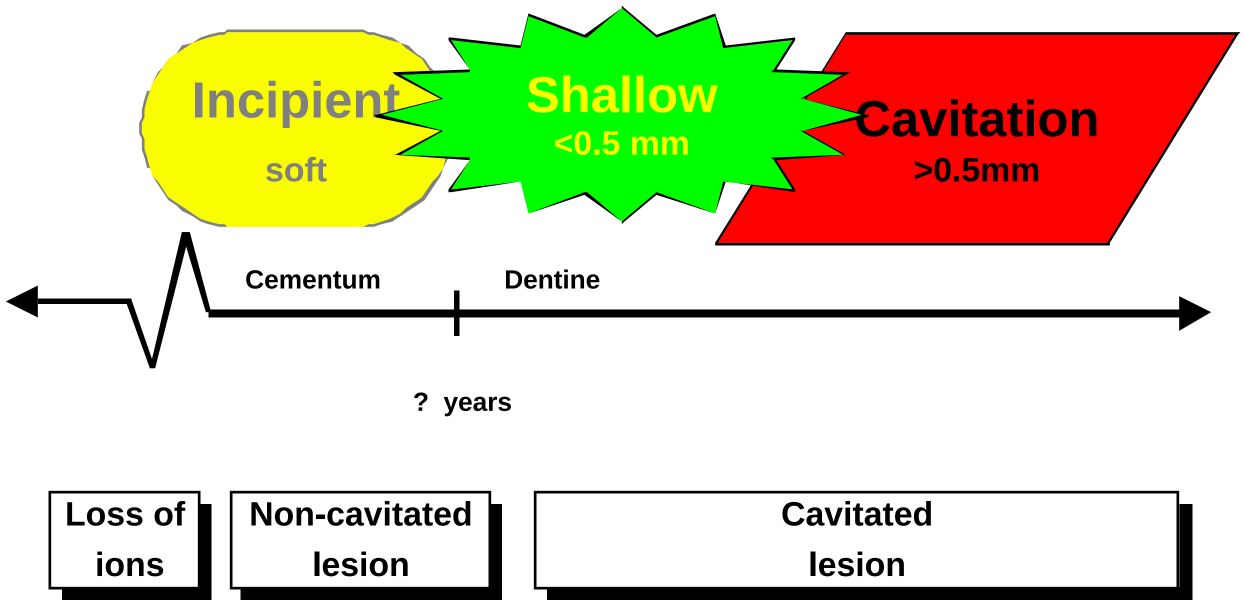


Figure 2- Natural history of root caries



References

Banting DW. Carious lesions on the roots of teeth: a review for the general practitioner. J Canad Dent Assoc 1976;10:496-504.

Banting DW. Factors associated with root caries initiation. PhD Dissertation. Faculty of Graduate Studies, University of Western Ontario, 1988.

Banting DW. Diagnosis and prediction of root caries. Adv Dent Res 1993; 7(2):80-6.

Banting DW, Ellen RP, Fillery ED. Prevalence of root surface caries among institutionalized older persons. Community Dent Oral Epidemiol 1980;8:84-8.

Banting DW, Ellen RP, Fillery ED. A Longitudinal study of root caries: baseline and incidence data. J Dent Res 1985; 64(9):1141-4.

Banting DW, Papas A, Clark DC, Proskin HM, Schultz M, Perry R. The effectiveness of 10% chlorhexidine varnish treatment on dental caries incidence in adults with dry mouth. Gerodontology 2001;17(2):2-11.

Bauer JG, Cretin S, Schweitzer SO, Hunt RJ. The reliability of diagnosing root caries using oral examinations. J Dent Educ 1988;52(11):622-9.

Beck J. The epidemiology of root surface caries. J Dent Res 1990;69(5):1216-21.

Beck JD, Hunt RJ, Hand JS, Field HM. Prevalence of oot and coronal caries in a noninstitutionalized older population. J Am Dent Assoc 1985;111:964-8.

Beighton D, Lynch E, Heath MR. A microbilogical study of primary root-caries lesions with different treatment needs. J Dent Res 1993;72(3):623-29.

Billings RJ, Brown LR, Kaster AG. Contemporary treatment strategies for root surface caries. Gerodontics 1985;1:20-7.

Billings RJ. Restoration of carious lesions of the root. Gerodontology 1986;5:43-9.

Billings RJ, Banting DW. Future directions for root caries research. Gerodontology 1993; 10(2):105-8.

Collier FI, Heath MR, Lynch E, Beighton D. Assessment of the clinical status of primary root caries lesions using an enzymatic dye. Caries Res 1993;27(1):60-4.

Community Dental Health Services Research Unit. Progression of Approximal carious lesions: a review. Clinical decision-making report No. 1, 1993.

Community Dental Health Services Research Unit. When to place an initial restoration. Quality Assurance Report No. 9, 1995.

Fejerskov O, Luan WM, Nyvad B, Budtz-Jorgensen E, Holm-Pedersen P. Active and inactive root surface caries lesions in a selected group of 60- to 80-year-old Danes. Caries Res 1991;25:385-91.

Fleiss JL. Statistical methods for rates and proportions. New York:John Wiley, 1981:pp. 146-7.

Fletcher RH, Fletcher SW, Wagner EH (1988). Clinical Epidemiology- the Essentials. 2nd ed. Baltimore: Williams & Wilkins.

Frank RM. Structural events in the caries process in enamel, cementum, and dentin. J Dent Res 1990;69(2)(Spec):559-66.

Fure S. Five-year incidence of coronal and root caries in 60-,70- and 80-year-old Swedish individuals. Caries Res 1997;31:249-58.

Gilbert GH, Duncan RP, Dolan TA, Foerster U. Twenty-four month incidence of root caries among a diverse group of adults. Caries Res 2001; submitted for publication.

Graves RC, Disney JA, Beck JD, Abernathy JR, Stamm JW, Bohannan HM. The University of North Carolina caries risk assessment study: caries increments of misclassified children. Community Dent Oral Epidemiol 1992:20:167-74.

Hand JS, Hunt RJ, Beck JD. Coronal and root caries in older Iowans: 36-month incidence. Gerodontics 1988:4:136-9.

Hazen SP, Chilton NW, Mumma RD. The problem of root caries. 1. literature review and clinical description. J Am Dent Assoc 1973;86:137-44.

Hellyer PH, Beighton D, Heath MR, Lynch E. Root caries in older people attending a general practice in East Sussex. Brit Dent J 1990;169:201-6.

Hellyer PH, Lynch E. The diagnosis of root caries- a review. Geordontology 1991;9(4):95-12.

Hix JO, O'Leary TJ. The relationship between cemental caries, oral hygiene status and fermentable carbohydrate intake. J Periodontol 1976;47:398404.

Kraemer HC. Evaluating medical tests: objective and quantitative guidelines. Newbury Park, California: Sage Publications, 1992.

Lawrence HP, Hunt RJ, Beck JD. Five-year root incidence rates and intraoral distribution of root cariers among community-dwelling older adults. Caries Res 1996;30:169-79.

Leake J. The management of root caries. NIH Consensus Conference on Diagnosis and Management of Dental Caries Throughout Life, 2001.

Leske GS, Ripa LW. Three-year root caries increments: an analysis of teeth and surfaces at risk. Gerodontology 1989;8(1):17-21.

Locker D. Incidence of root caries in an older Canadian population. Community Dent Oral Epidemiol 1996;24:403-7.

Lynch E. The diagnosis and management of primary root caries, PhD Dissertation, London: University of London, 1994.

Lynch E, Beighton D. A comparison of primary root caries lesions classified according to colour. Caries Res 1994;28(4):233-9.

Matthews DC, Banting DW, Bohay RN. The Use of diagnostic tests to aid clinical diagnosis. J Canad Dent Assoc 1995;61(9):785-91.

Mojon P, Favre P, Chung JP, Budtz-Jorgensen E. Examiner agreement on caries detection and plaque accumulation during dental surveys of elders. Gerodontology 1995;12(1):49-55.

National Institute for Dental Research (NIDR). Oral health of United States adults: the national survey of oral health in U.S. employed adults and seniors: 1985-1986. Washington: US Department of Health and Human Services, Public Health Services, N. I.H. Publication No. 87-2868, 1987.

Nordenram G, Bergvit A., Johnson G, Henriksson CO, Anneroth G. Macroscopic and radiologic examination of proximal root surface caries. Acta Odont Scand 1988;46:95-99.

Powell LV, Leroux BG, Persson RE, Kiyak HA. Factors associated with caries incidence in an elderly population. Community Dent Oral Epidemiol 1998;26(3):170-6.

Provenza DV. Fundamentals of Oral Histology and Embryology. Second edition. Philadelphia: Lea & Febiger, 1988. Ch. 5,6 & 7.

Ravald N. Root surface caries. Current Opinion in Periodontol 1994:78-86.

Ravald N, Hamp S-E, Birkhed D. Long-term evaluation of root surface caries in periodontally treated patients. J Clin Periodontol 1986;13:758-67.

Ravald N, Birkhed D, Hamp S-E. Root caries susceptibility in periodontally treated patients. J Clin Periodontol 1993;20:124-9.

Ravald N, Birkhed D. Factors associated with active and inactive root caries in patients with periodontal disease. Caries Res 1991;25:377-84.

Research Triangle Institute, Diagnosis and management of dental caries, Evidence Report, Volumn 1, University of North Carolina at Chapel Hill. August 18, 2000.

Rosen B, Birkhed D, Nilsson K, Olvari G, Egelberg J. Reproducibility of clinical caries diagnoses on coronal and root surfaces. Caries Res 1996;30(1):1-7.

Sackett DL, Haynes RB, Guyatt GH, Tugwell P. Clinical Epidemiology-A Basic Science for Clinical Medicine. Boston: Little, Brown and Company, 1991.

Saunders RH, Handelman SL. Coronal and root decay in institutionalized older adults. NY State Dent J 1991;57(8):25-8.

Shaeken MJM, Keltjens HMAM, van der Hoeven JS. Effects of fluoride and chlorhexidine on the microflora of dental root surfacs and progression of root-surface caries. J Dent Res 1991;70(2):150-3.

Scheinin A, Pienihakkinen K, Tiekso J, Holmberg S, Fukuda M, Suzuki A. Multifactorial modeling for root caries prediction: 3-year follow-up results. Community Dent Oral Epidemiol 1994;22(2):126-9.

Schupbach P, Guggenheim B, Lutz F. Human root caries: histopathology of initial lesions in cementum and dentine. J Oral Pathol Med 1989;18(3):146-56.

Schupbach P, Guggenheim B, Lutz F. Histopathology of root surface caries. J Dent Res 1990;69(5):1195-204.

Scott JH, Symons NB. Introduction to dental anatomy. Edinburgh: Churchill Livingstone. 1974. Ch. 11,12 & 14.

Sumney DL, Jordan HV, Englander HR. The prevalence of root surface caries in selected populations. J Periodontol 1973;44: 500-4.

Titus HW. Root caries: some facts and treatment methods. Am J Dent 1991;4:61-8.

van der Veen MH, ten Bosch JJ. An in vitro evaluation of fluorescin penetration into natural root surface carious lesions. Caries Res 1993;27(4):258-61.

van der Veen MH, Tsuda H, Arends J, ten Bosch JJ. Evaluation of sodium fluorescin for quantitative diagnosis of root caries. J Dent Res 1996;75(1):588-93.

van der Veen MH, ten Bosch JJ. A fiber-optic setup for quantification of root surface demineralization. Eur J Oral Sci 1996;104(2 (Pt 1)):118-22.

Vehkalahti MM, Rajala M, Tuominen R, Paunio I. Prevalence of root caries in the adult Finnish population. Community Dent Oral Epidemiol 1983;11:188-190.

Wallace MC, Retief DH, Bradely EL. The 48-month increment of root caries in an urban population of older adults participating in a preventive dental program. J Public Health Dent 1993;53(3):133-7.

Wefel JS, Clarkson BH, Heilman JR. Natural root caries: a histologic and microradiographic evaluation. J Oral Pathol 1985;14(8):615-23.

Wilkinson SC, Higham SM, Ingram GS, Edgar WM. Visualization of root caries lesions by means of a diazonium dye. Adv Dent Res 1997;11(4):515-22.

Zambon JJ, Kasprzak SA. The microbiology and histopathology of human root caries. Amer J Dent 1995;8(6):323-8.

Zoellner A, Bragger U, Fellmann V, Gaengler P. Correlation between clinical scoring of secondary caries at crown margins and histologically assessed extent of the lesions. Internat J Prosthodont 2000;13(6):453-459.